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NASA DILUTION JET MIXING - PHASE III

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Many of the gas turbine combustors in operation use multiple rows of dilution jets, and some of them have geometries that are different from circular holes. The data base available in the literature is generally applicable to a single row of circular holes.

On the basis of the data obtained in References 1, 2, and 3, empirical correlations have been developed (References 2, 3, and 4) that provide a very useful design tool. However, these correlations are applicable only within the range of the generating test conditions.

The objectives of the Phase III program are to:

- Extend the data base on mixing of a single-sided row of jets with a confined cross flow.
- Collect data base on mixing of multiple rows of jets with confined cross flow.
- Develop empirical jet mixing correlations.
- Perform limited 3-D calculations for some of these test configurations.

The test portion of Phase III has been completed. The tests were performed with uniform mainstream conditions for several orifice plate configurations. A schematic of the test section and the orifice configurations are shown in Figure 1. The orifice plate plenum has provisions to supply independently controlled air flows to each of the rows of jets. The orifice air supply and the main air supply lines have perforated plates to ensure uniform flow distribution. Temperature and pressure measurements were made in the test section at 4 axial and 11 transverse stations. These measurements were made with a 60-element rake probe. The test results for some of these cases are discussed in this paper.

RESULTS AND DISCUSSION

The temperature field results are presented in three-dimensional oblique views of temperature difference ratio, THETA:

$$\text{THETA} = \frac{(T_m - T)}{(T_m - T_j)}$$

where:

T_m = Mainstream Temperature

T_j = Jet Temperature

T = Local Temperature

Figure 2 provides a comparison between the theta distributions for streamlined slots at a jet-to-cross-stream momentum flux ratio, J, of 6.6 and those with equivalent area circular holes at comparable momentum flux ratio. The streamlined slots have deeper jet penetration at X/H_o = 0.5 and 1.0 compared with circular holes. However, at X/H_o = 2.0, both orifice configurations produce very similar temperature distribution. At moderate momentum flux ratios, the streamlined slots overpenetrate to the opposite duct wall, followed by enhanced mixing (Figure 3). The temperature distributions for this case are quite different from those of circular jets at comparable momentum flux ratio.

Figure 4 presents a comparison of temperature distributions between bluff and streamlined slots at comparable momentum flux ratios. At X/H_o = 0.5, the streamlined slots have deeper jet penetration than bluff slots. However, at X/H_o = 2.0, both of these orifice configurations show similar, completely mixed temperature distributions.

Figure 5 compares the temperature distribution for two in-line rows of jets with A_j/A_m = 0.049 for each row at J = 6.5, with an equivalent area circular hole having the same S/H_o ratio, at comparable momentum flux ratio. The two configurations have very similar temperature distributions. At a higher momentum flux ratio of 26.3, similar characteristics are observed (Figure 6).

Figure 7 presents the temperature distributions for a double row of jets, with the first row having A_j/A_m = 0.049 and S/H_o = 0.25. In the figure, these results are compared with those for a single row of jets having the same total geometric area at comparable momentum flux ratio. At X/H_o = 0.5, the double row of jets show a flatter peak theta distribution than the single row of jets. But beyond X/H_o = 1.0, the two orifice configurations have very similar temperature profiles. In Figure 8, the temperature distributions of these two orifices are compared at moderate momentum flux ratios. For this case, the double row of jets have mixing rates (in both vertical and transverse directions) comparable to the single row of jets with equivalent area.

The following conclusions can be made from these results:

- The effects of orifice shapes are significant only in the regions close to the jet injection plane ($X/H_o<1$). The temperature distributions in regions beyond X/H_o = 1 are similar to those with equivalent area circular holes.

- At the same S/H_O and momentum flux ratio, double rows of in-line jets have temperature distributions similar to a single row of jets with equivalent area.

REFERENCES

1. Walker, R. E.; and Kors, D. L.: Multiple Jet Study Final Report. NASA CR-121217, June 1973.

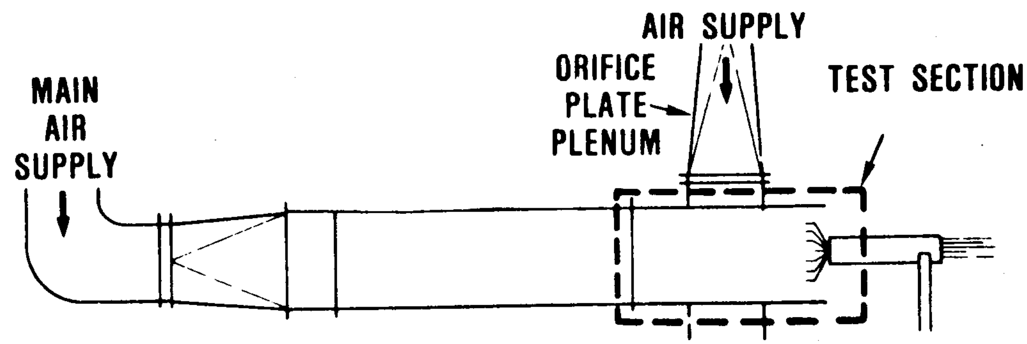
2. Srinivasan, R.; Berenfeld, A.; and Mongia, H.: Dilution Jet Mixing Phase I Report. Garrett Turbine Engine Co., Phoenix, AZ, Garrett Report 21-4302, November 1982 (NASA CR-168031).

3. Srinivasan, R.; Coleman, E.; Johnson, K.; and Mongia, H.: Dilution Jet Mixing Program Phase II Report. Garrett Report 21-4804, December 1983 (NASA CR-174624).

4. Holdeman, J. D.; and Walker, R. E.: Mixing of a Row of Jets with a Confined Crossflow. AIAA Journal, vol. 15, no. 2, February 1977, pp. 243-249 (AIAA Paper 76-48; NASA TM-71821).

Figure 1. Schematic of the test section and orifice plates

TEST RIG GEOMETRY



ORIFICE CONFIGURATIONS

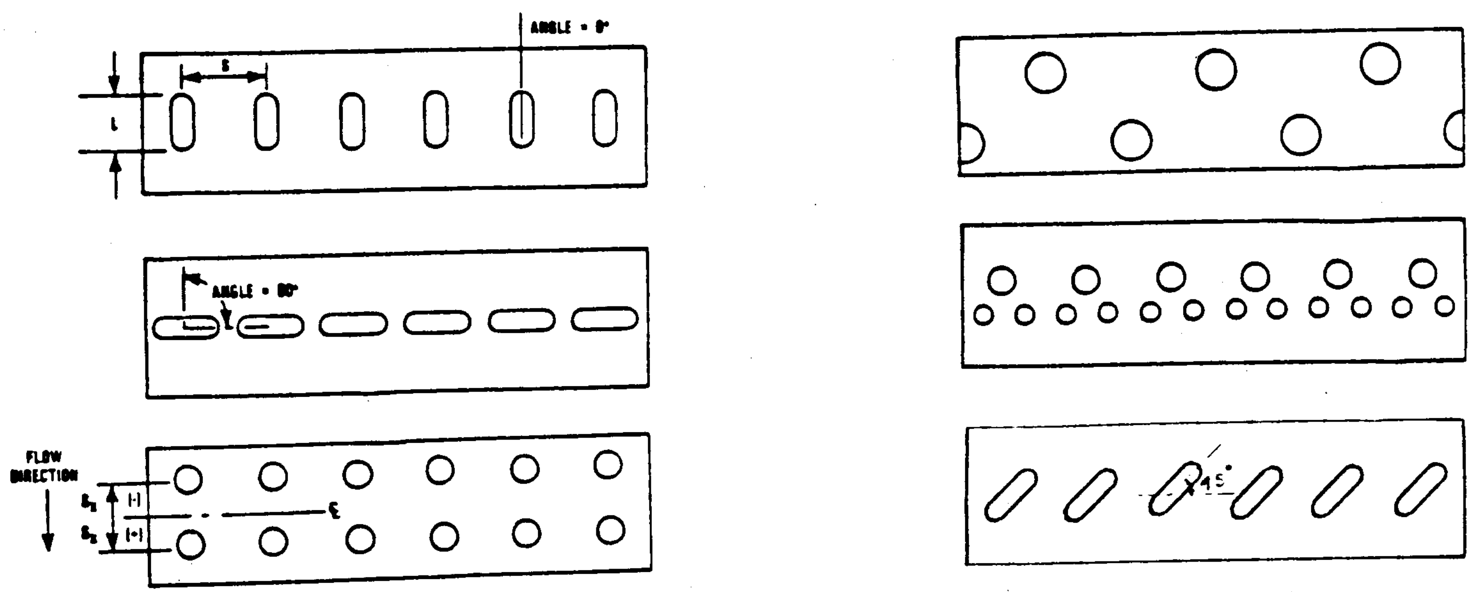


Figure 2. Comparison of temperature distributions between streamlined slots and circular holes at low momentum flux ratios.

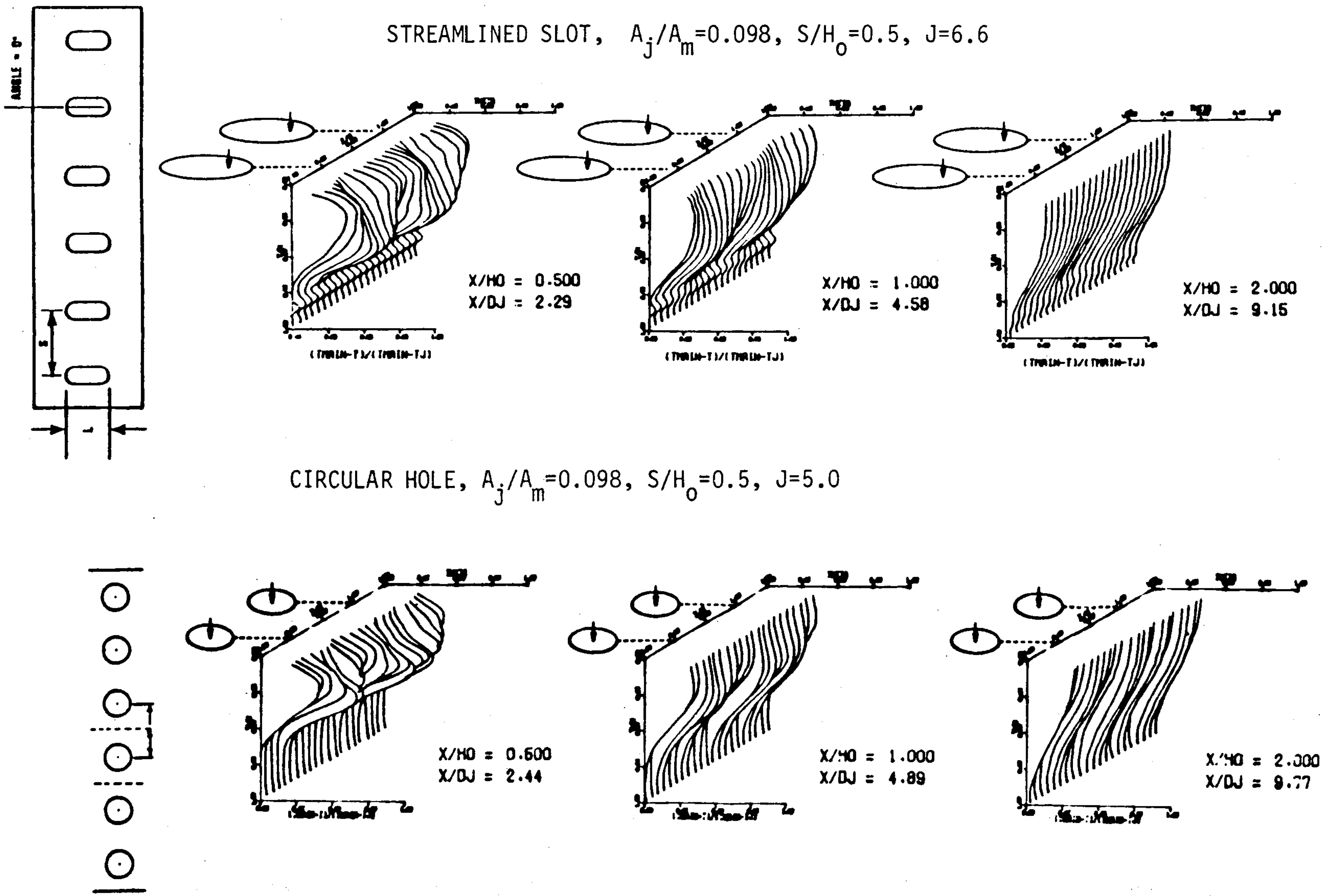


Figure 3. Comparison of temperature distributions between streamlined slots and circular holes at moderate momentum flux ratios.

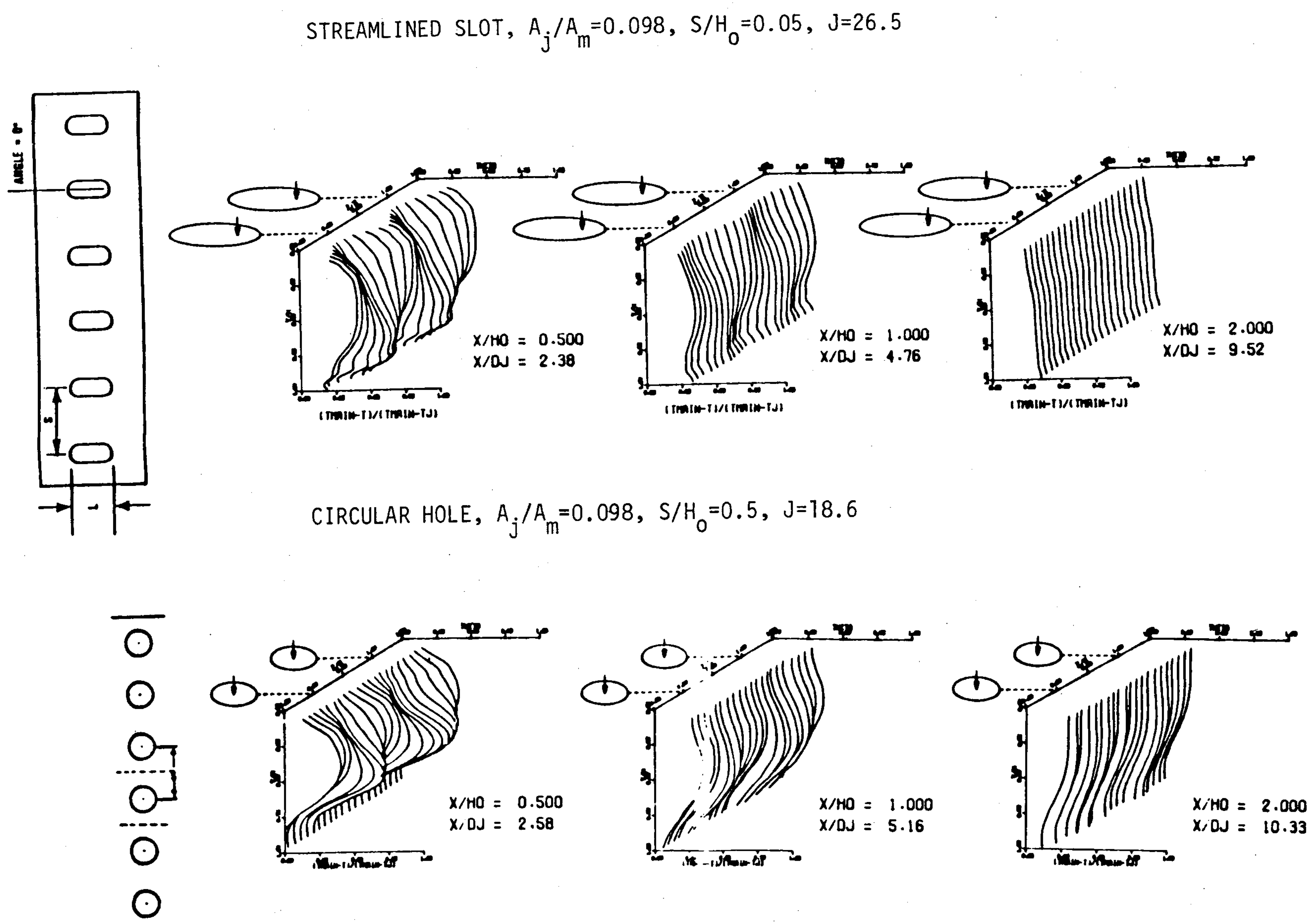


Figure 4. Comparison of temperatures distributions between bluff and streamlined slots at moderate momentum flux ratios.

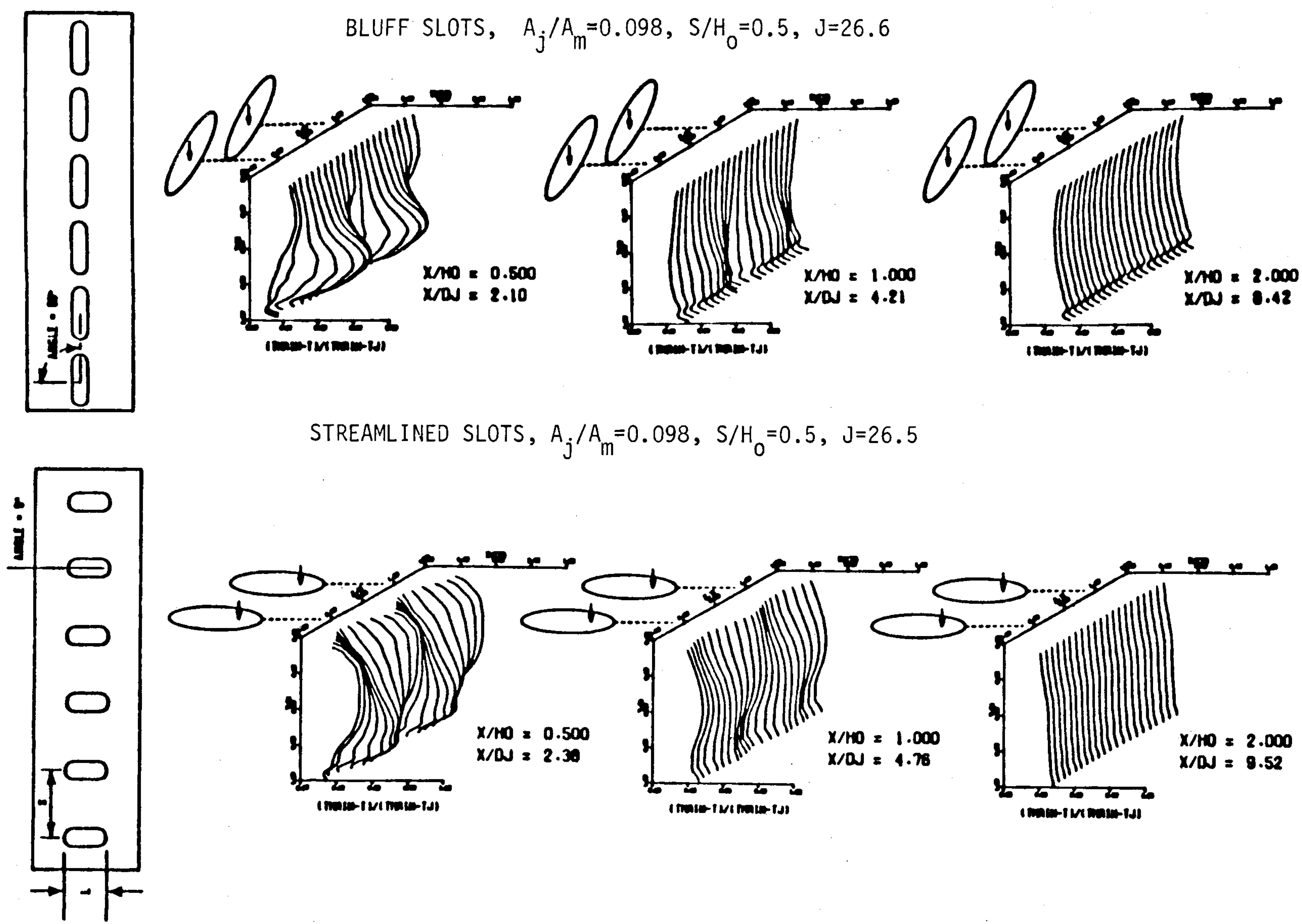


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Figure 5. Comparison of temperature distributions between two rows of jets and an equivalent single row of jets.

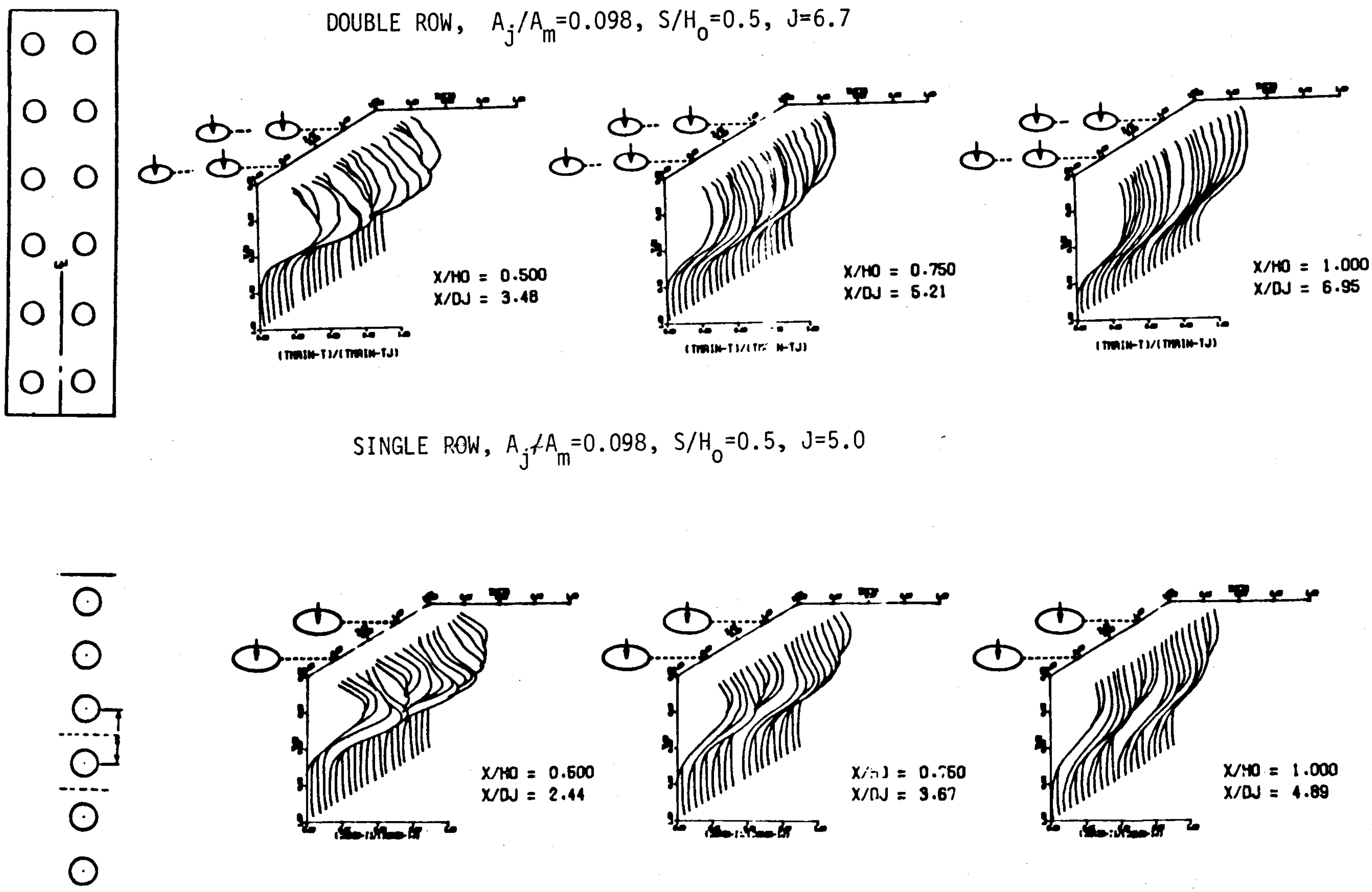
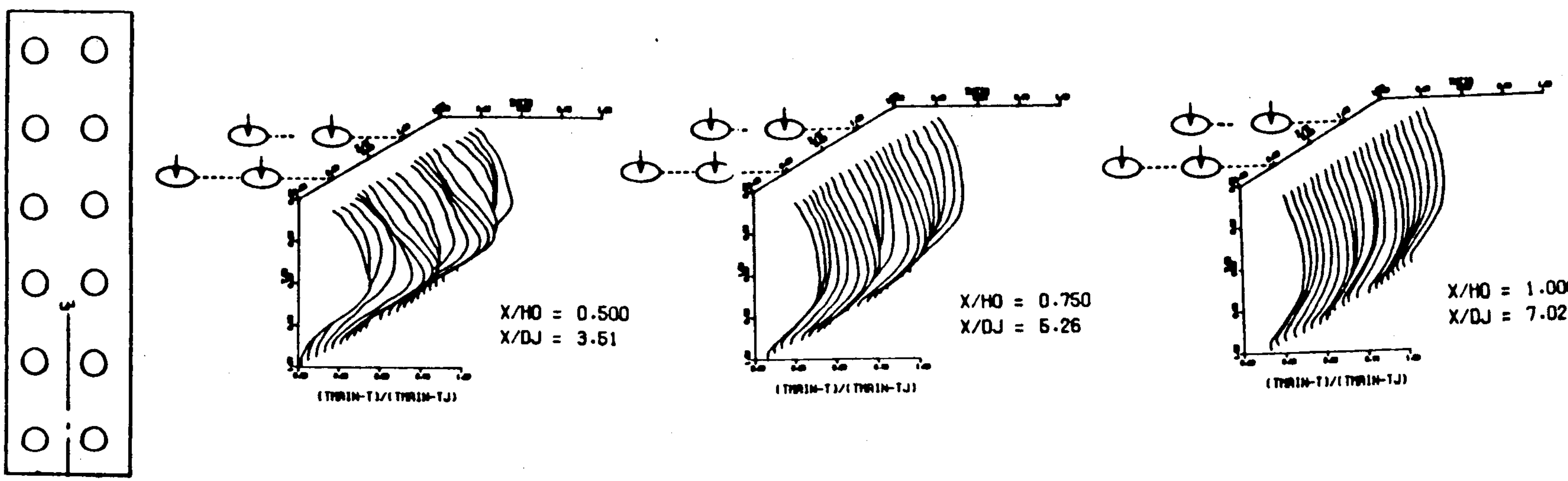


Figure 6. Comparison of temperature distributions between single and double rows of jets, $S/H_o=0.5$

DOUBLE ROW OF JETS, $A_j/A_m=0.098$, $J=26.3$



SINGLE ROW OF JETS, $A_j/A_m=0.098$, $J=18.6$

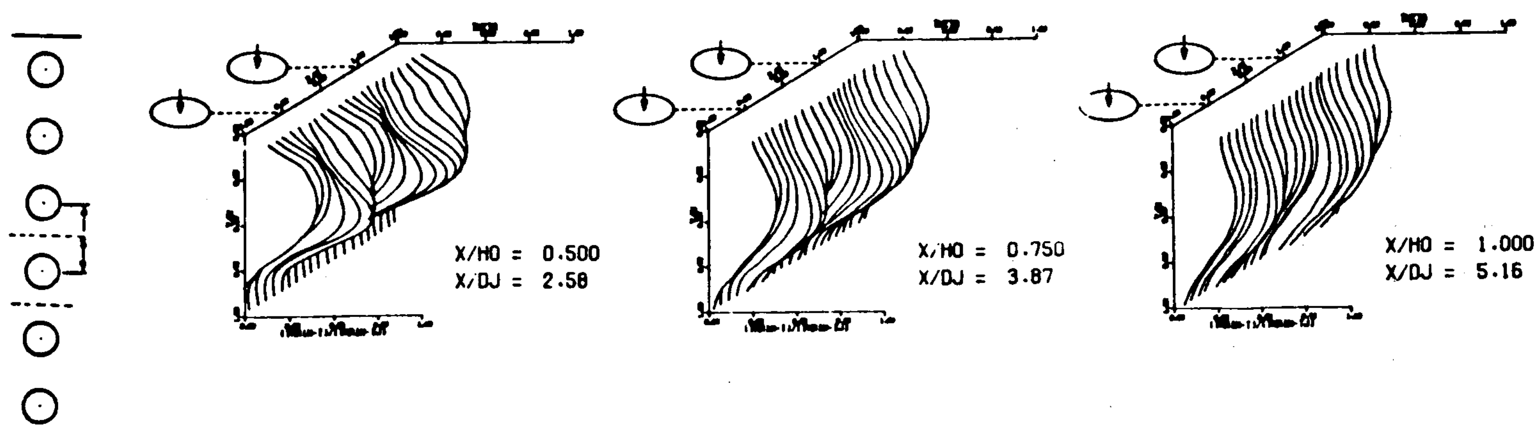


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Figure 7. Comparison of temperature distributions between a double row of dissimilar holes and a single row of equivalent holes at low momentum flux ratio.

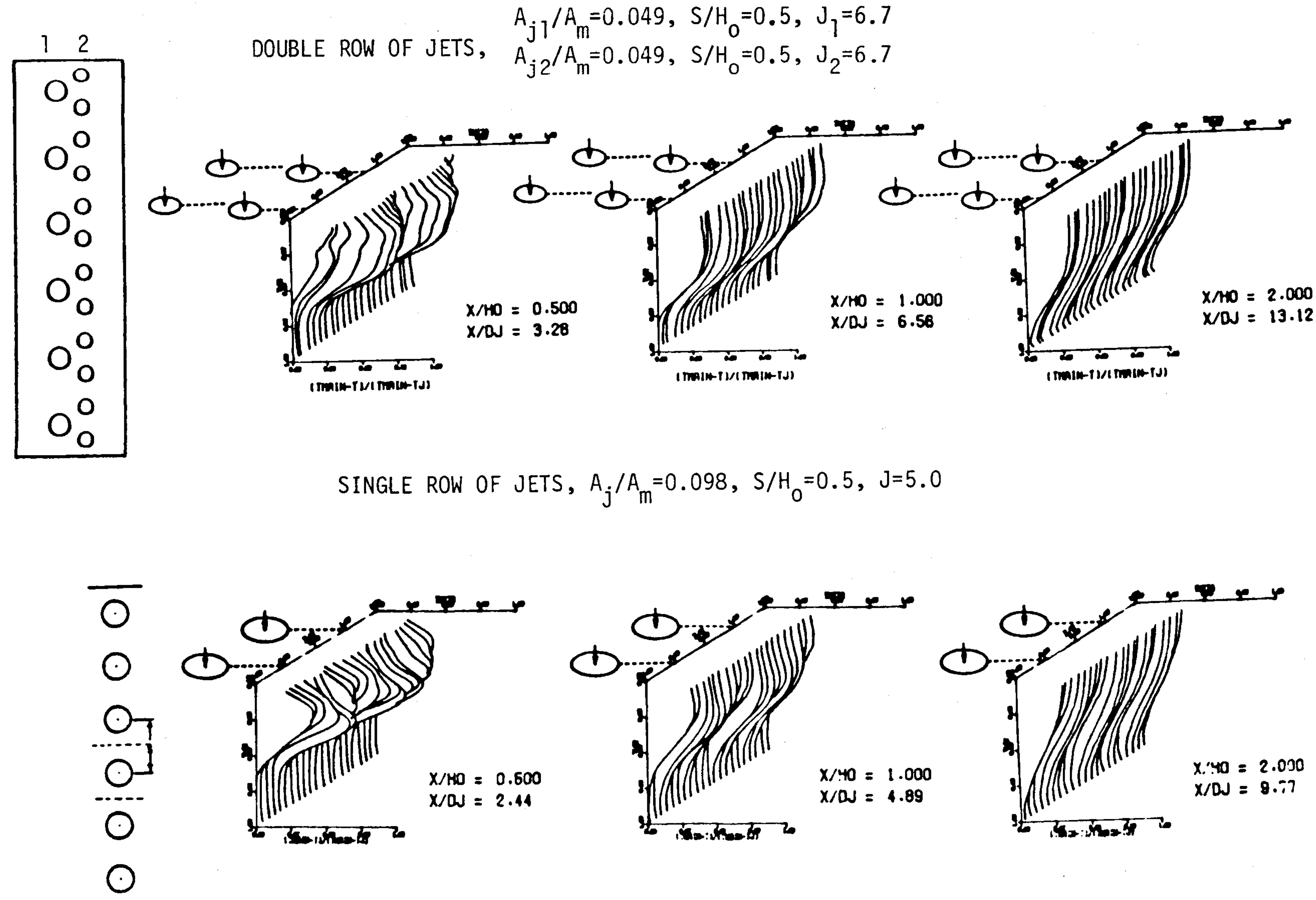

Figure 8. Comparison of temperature distributions between a double row of dissimilar holes and a single row of equivalent holes at moderate momentum flux ratio.